# GEOCHEMICAL CONSIDERATIONS FOR HOT, DRY ROCK SYSTEMS*

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Circulating systems intended to model the P-T conditions found in the natural HDR (Hot Dry Rock) geothermal system at Los Alamos have been built. Experiments with these systems have determined the following parameters for the "down hole" reservoir: sample weight loss, circulating solution composition, textural changes in the rock, mineral loss from the rock and effects of chemical additives on rock erosion. The analyses of solutions generated from rock-water interactions in the experimental systems show the extremely dilute nature of the working fluid. These solutions are not brines. Silica scaling in the surface heat exchanger was found to account for the difference between loss of sample rate and analyzed silica in the solution. The weight loss data indicate that there was continuous transport of silica from the "down hole" rock to the heat exchanger.

Experiments contrasting felsic and mafic rocks in the HDR concept indicate that a reservoir consisting of glass bearing basaltic rock would tend to produce greater scaling problems than systems emplaced in granite.

Experimental results suggest that $Na_2CO_3$ solutions may provide a means of increasing permeability and thereby increasing the effective heat transfer area of the reservoir.

A brief description will be given of a small test loop for simulating the flow of a geothermal solution through a heat exchanger. This loop, which is being built, will be used to study the coagulation and precipitation of silica under conditions similar to those expected in the field.

Results will be presented of some static experiments on the solubility of silica in water at 200° and 250°C.

Mention will be made of the use of the PATHCALC code for the calculation of multicomponent equilibria in geothermal systems.

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## DISCLAIMER

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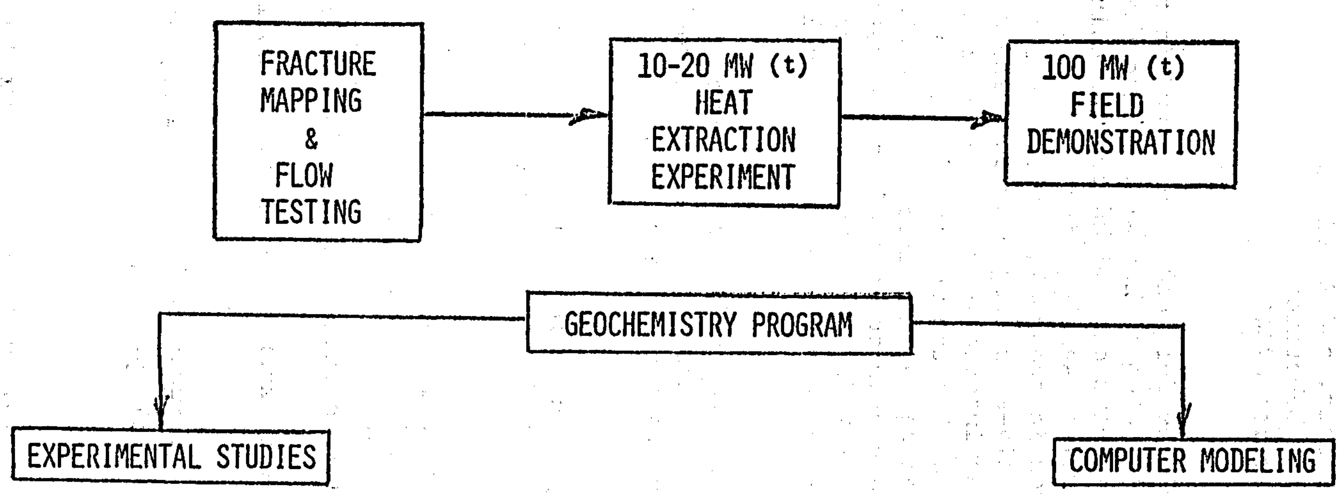
LASL HOT DRY ROCK PROJECT




1. ROCK DISSOLUTION KINETICS
   - TRANSPORT OF MATERIAL INTO CIRCULATING FLUID
2. GEOCHEMICAL ALTERATION
   - PHYSICAL AND CHEMICAL CHANGES IN FRACTURED RESERVOIR
3. ROCK PERMEABILITY
4. SILICA SOLUBILITY
   - USE OF ADDITIVES TO CONTROL SOLUBILITY
5. REPRECIPITATION KINETICS
   - SCALE DEPOSITION ON HEAT EXCHANGE SURFACES

6. MODEL FOR SINGLE AND POLYMINERALIC SYSTEMS
   - APPROACH TO EQUILIBRIUM
7. SCALE DEPOSITION KINETICS
   - CHEMICAL KINETICS
   - HEAT, MASS, AND MOMENTUM TRANSFER

Figure 1.

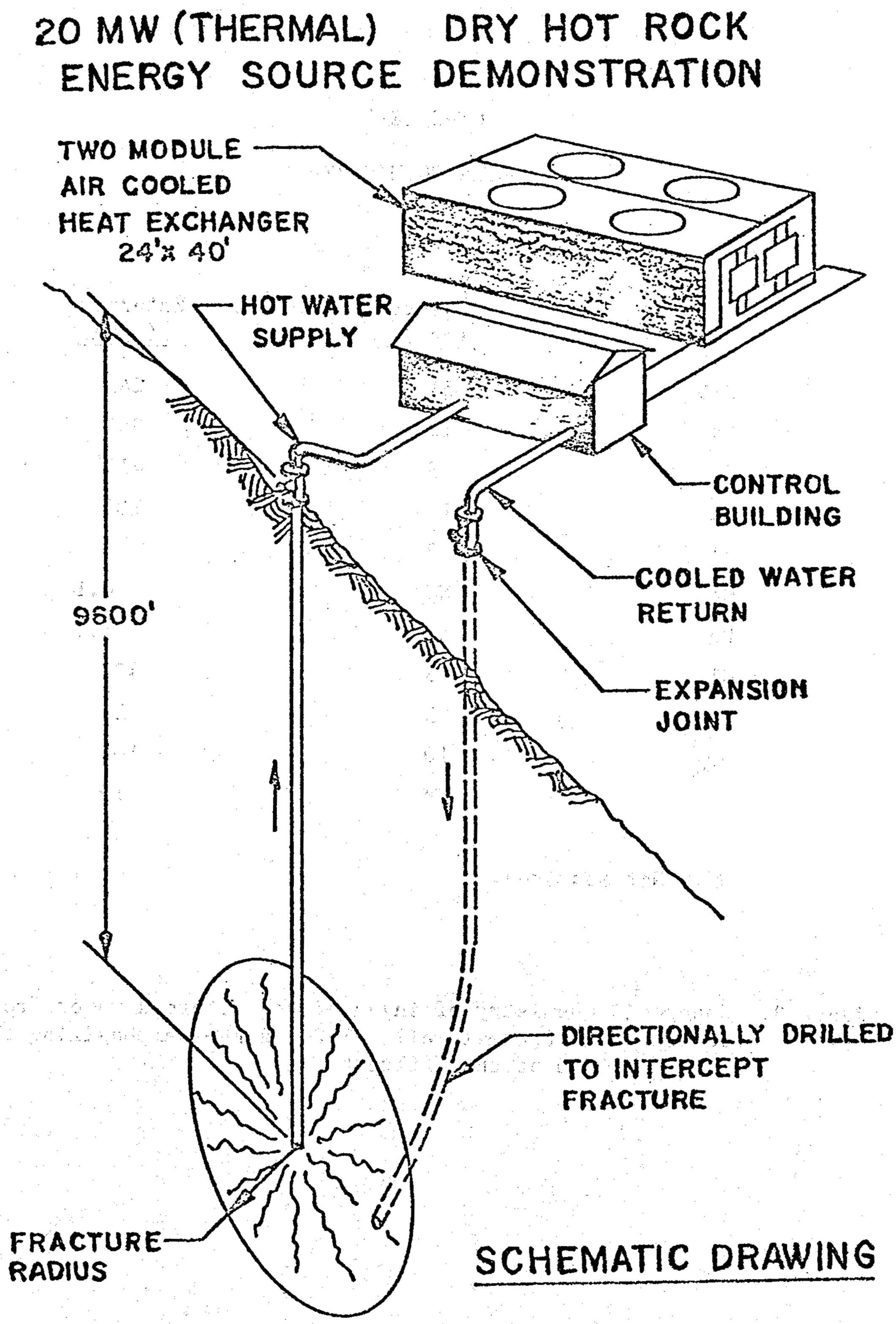



Figure 2. A schematic drawing of the LASL dry hot rock geothermal test facility.

GT-2/EE-1

WATER CHEMISTRY

| | Injected (ppm) | Returned (ppm) |
|---|---|---|
| $SiO_2$ | 51 | 241 |
| Na | 12 | 350 |
| K | 3 | 410 |
| Ca | 13 | 100 |
| Al | 0.7 | 1 |
| Mg | NM | 0.1 |
| Fe | NM | 1.5 |
| Cl | 3 | 402 |
| F | 3 | 16 |
| $SO_4$ | 10 | 162 |
| C | NM | 19 |

NM = Not Measured.

Figure 3. Change in chemistry of injected and returned water from the connected geothermal wells GT-2 and EE-1 emphasizing the dilute nature of the effluent.

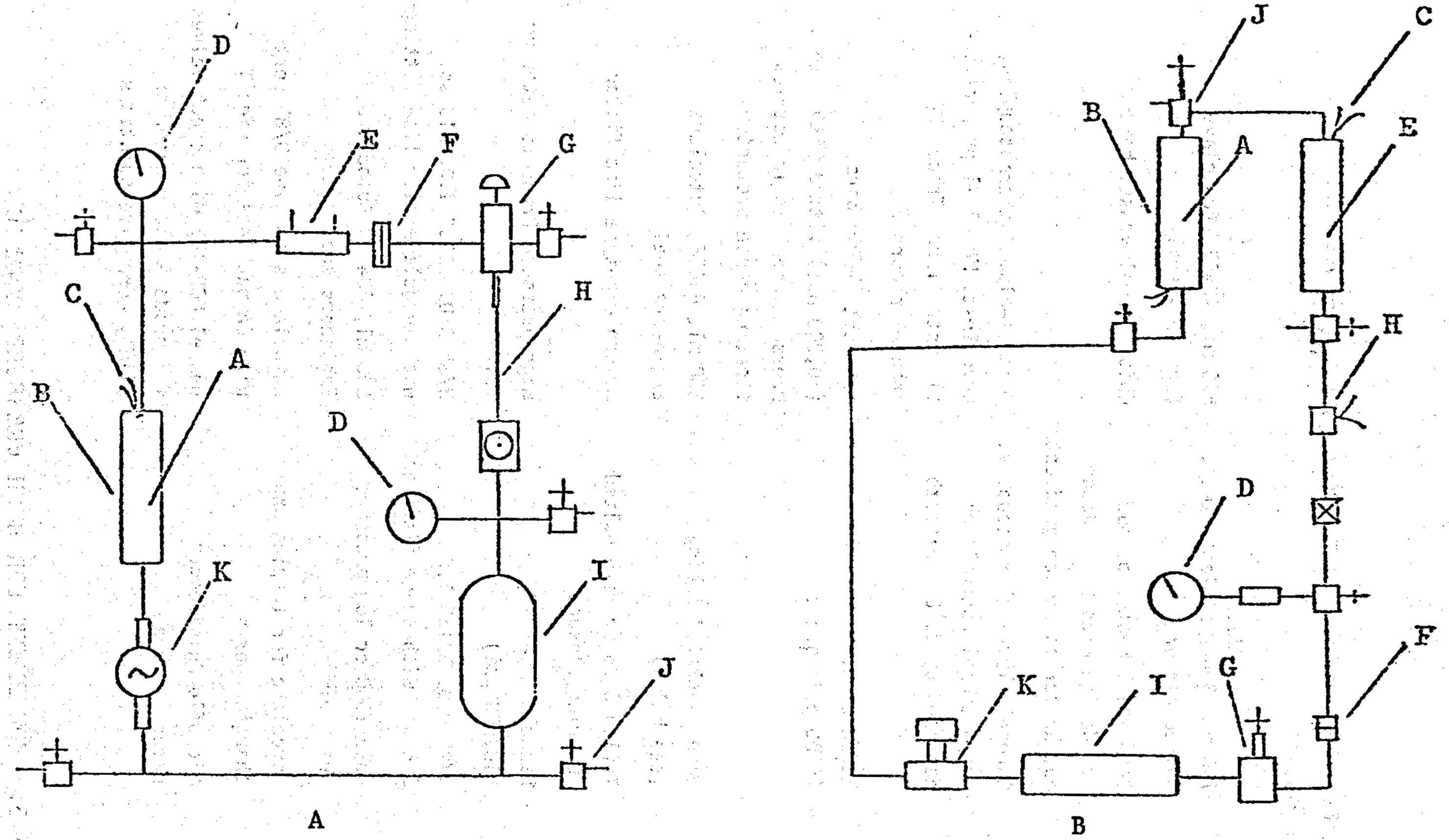



Figure 4. Circulating systems used to react rock cores. These systems were used to generate the data presented in Figs. 6 and 7. The key to this figure is presented in Fig. 5.

Ia: $P_{Tot}$ = 200 bars (3000 psi), T = 300°C; Ib: $P_{Tot}$ = 700 bars (10,000 psi), T = 300°C.

| | | Ia. | Ib. |
|---|---|---|---|
| A. | Reaction Vessel | 750 ml, 304 stainless steel, bolted closure | 500 ml, 4340E, Autoclave Engineers seal |
| B. | Heater | Clam shell heater of our own design with basal dough-nut heater to reduce gradients | Ohio Thermal vessel heater |
| C. | Temperature Measurement | Chromel-alumel thermocouples, proportional controllers designed by D. O. Whitcomb | Chromel-alumel thermocouples, Love Inst. Model 71 proportional controllers, Tracor 24 channel recorder |
| D. | Pressure Measurement | Marsh or U. S. 0-350 bars (5000 psi) gauge | Ashcroft 0-700 bars (10,000 psi) fitted with 1 to 1 Pressure Products Industries floating gauge protector |
| E. | Condenser | water jacketed tubing (see below) | 500 ml, 4340E, Autoclave Engineers seal |
| F. | Filter | Teflon 5-35 um with bolted "O" ring closure | Aminco cup-type line filter |
| G. | Back Pressure Regulator | Haskel 0-700 bars (10,000 psi) | High pressure Products metering valve |
| H. | Tubing and Fittings | 1/2" O.D. 5/16" I.D. 316 ss. with swage fittings. | 3/8" O.D. .203" I.D. 316 ss. with Autoclave slim line fittings |
| I. | Reservoir | Hoke 1000 cc low pressure reservoir | 500 ml, 4340E, Autoclave Engineers seal |
| J. | Valves | Autoclave for tapping and charging ports | Autoclave slim line 3/8" port with GA packings for high T |
| K. | Pump | Microflo Pulsifeeder Metering pump | Haskel MCP-188 with check valves for grade A clean water or mildly corrosive solutions |

Figure 5. EQUIPMENT FOR HIGH PRESSURE DYNAMIC CIRCULATING SYSTEMS

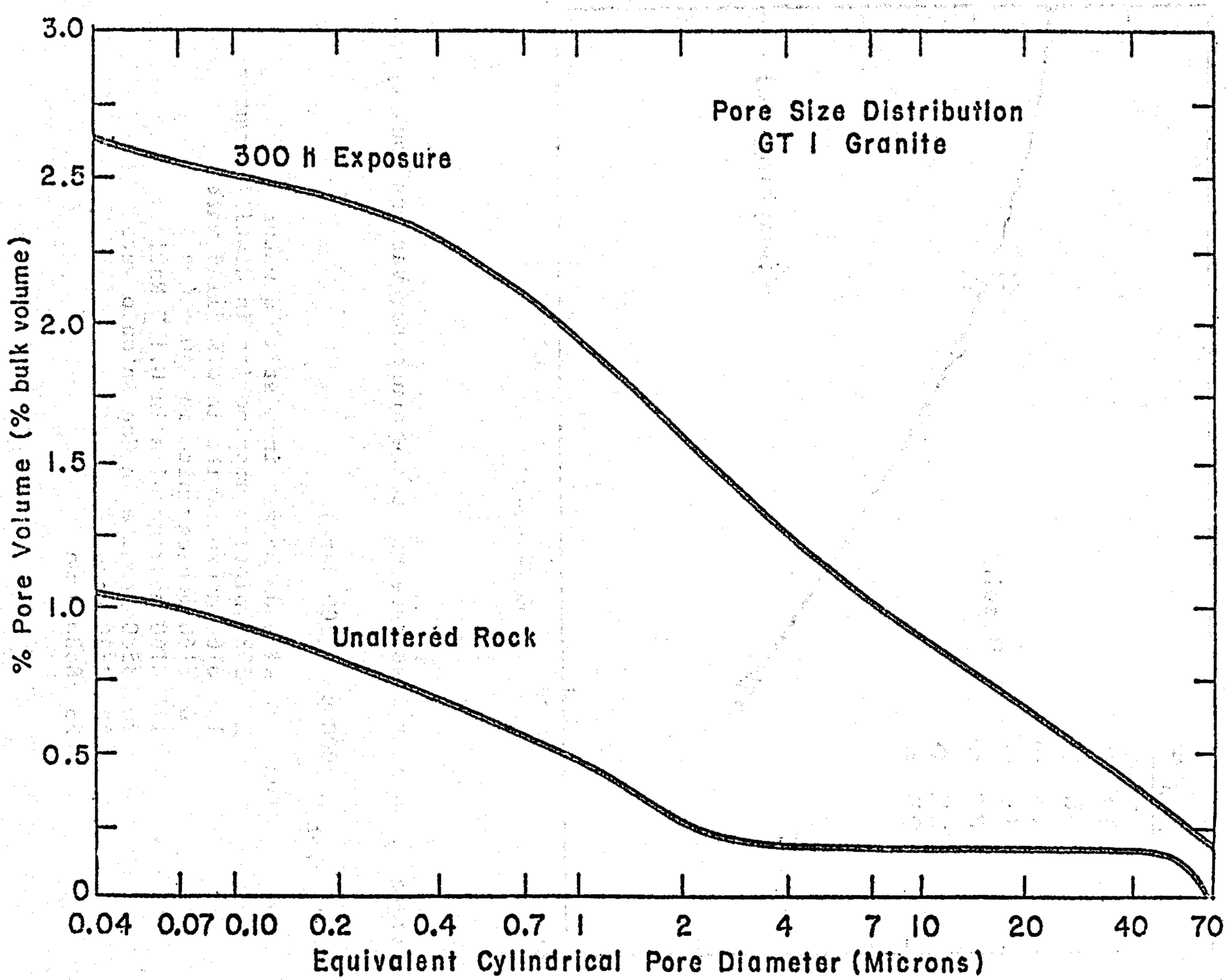



Figure 6. Percent pore volume vs. pore diameter for GT-1 granite showing increase in porosity after reaction with distilled water at 260°C for 300 h.

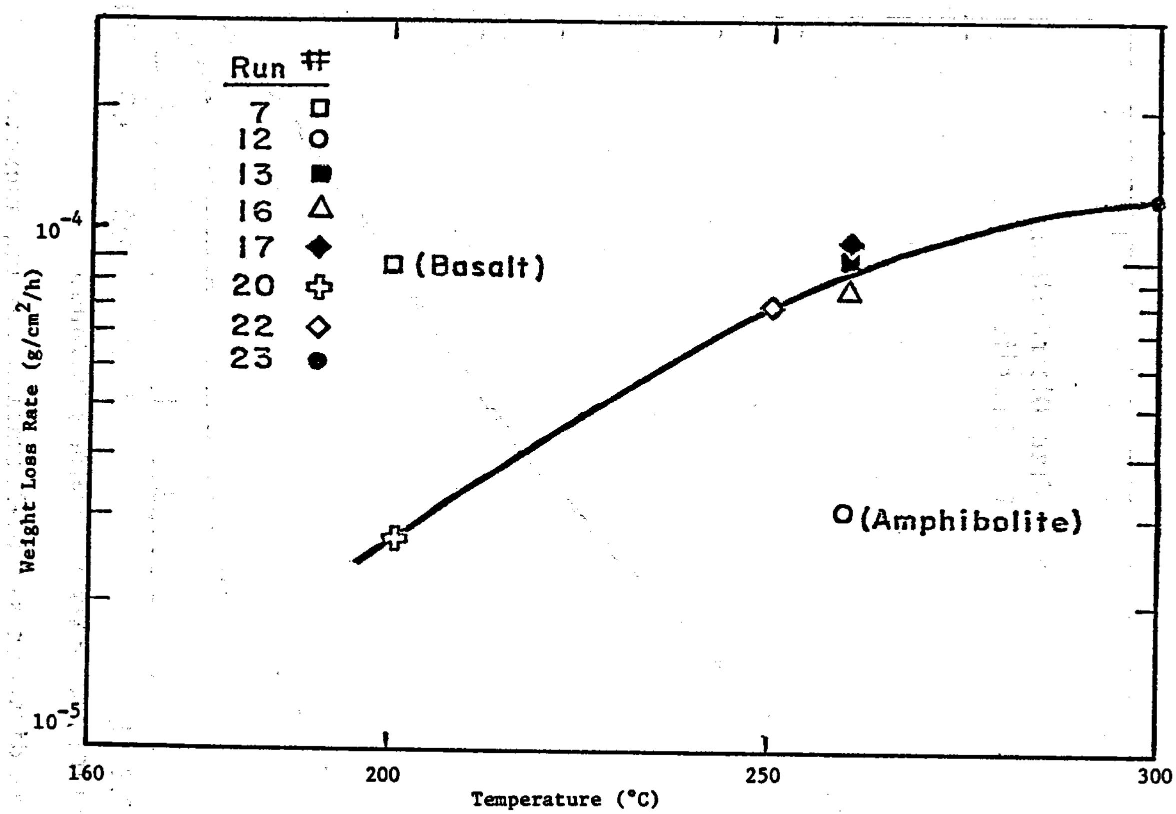
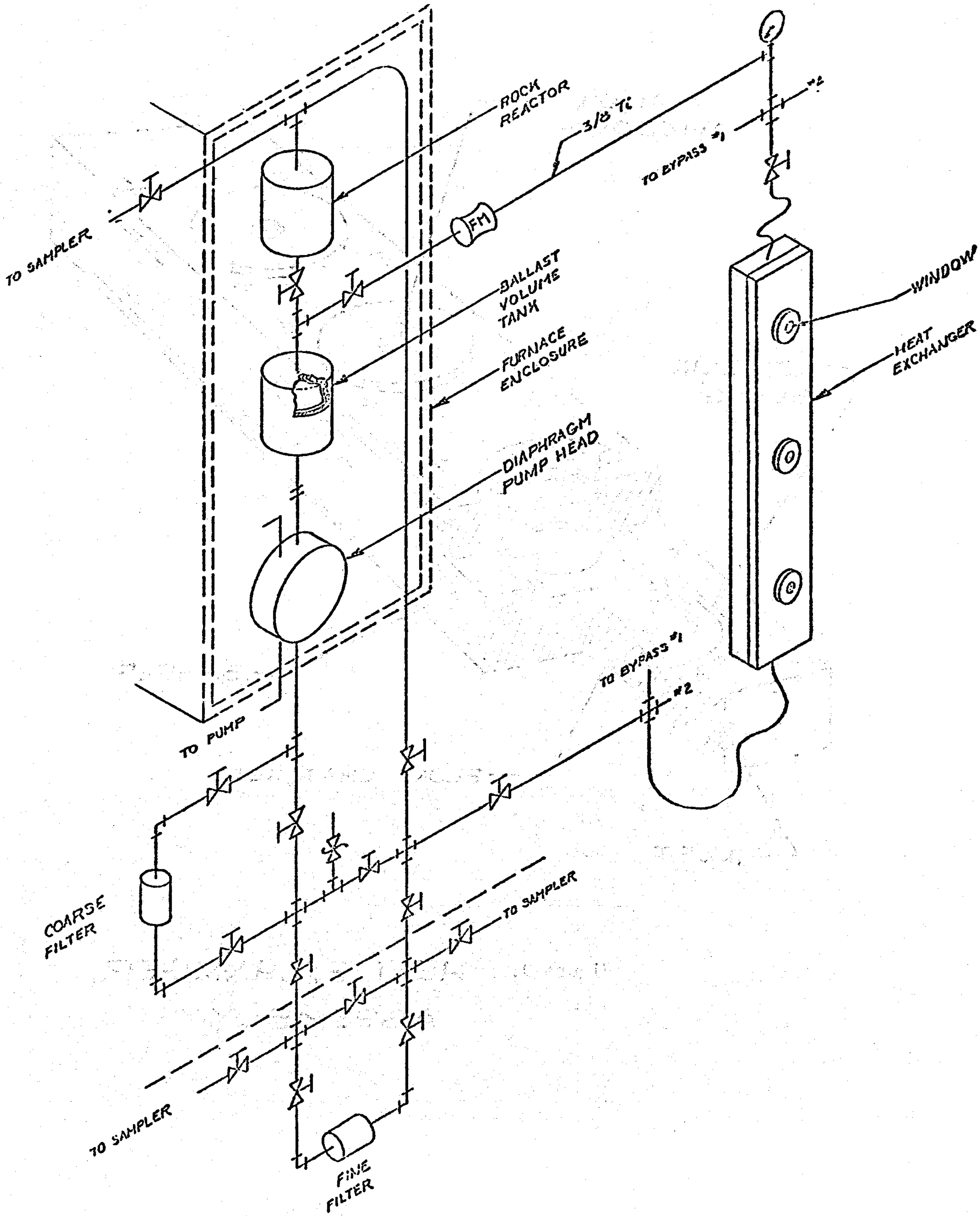



Figure 7. Weight loss rate vs. temperature for various rock types.

$P_{Tot}$ = 3000 psi (200 bars)

| | | |
|---|---|---|
| Run # | 7 | Kileaua basalt in distilled water |
| | 12 | 5984 biotite amphibolite in distilled water |
| | 13 | 6160 monzogranite in distilled water |
| | 16 | 6160 monzogranite in $H_2O + CO_2$ |
| | 17 | 6160 monzogranite in 0.1 N NaCl |
| | 20 | 8580 granite in San Antonio water |
| | 22 | 8580 same |
| | 23 | 8580 same |

Figure 8. Circulation Loop for Study of Silica Deposition



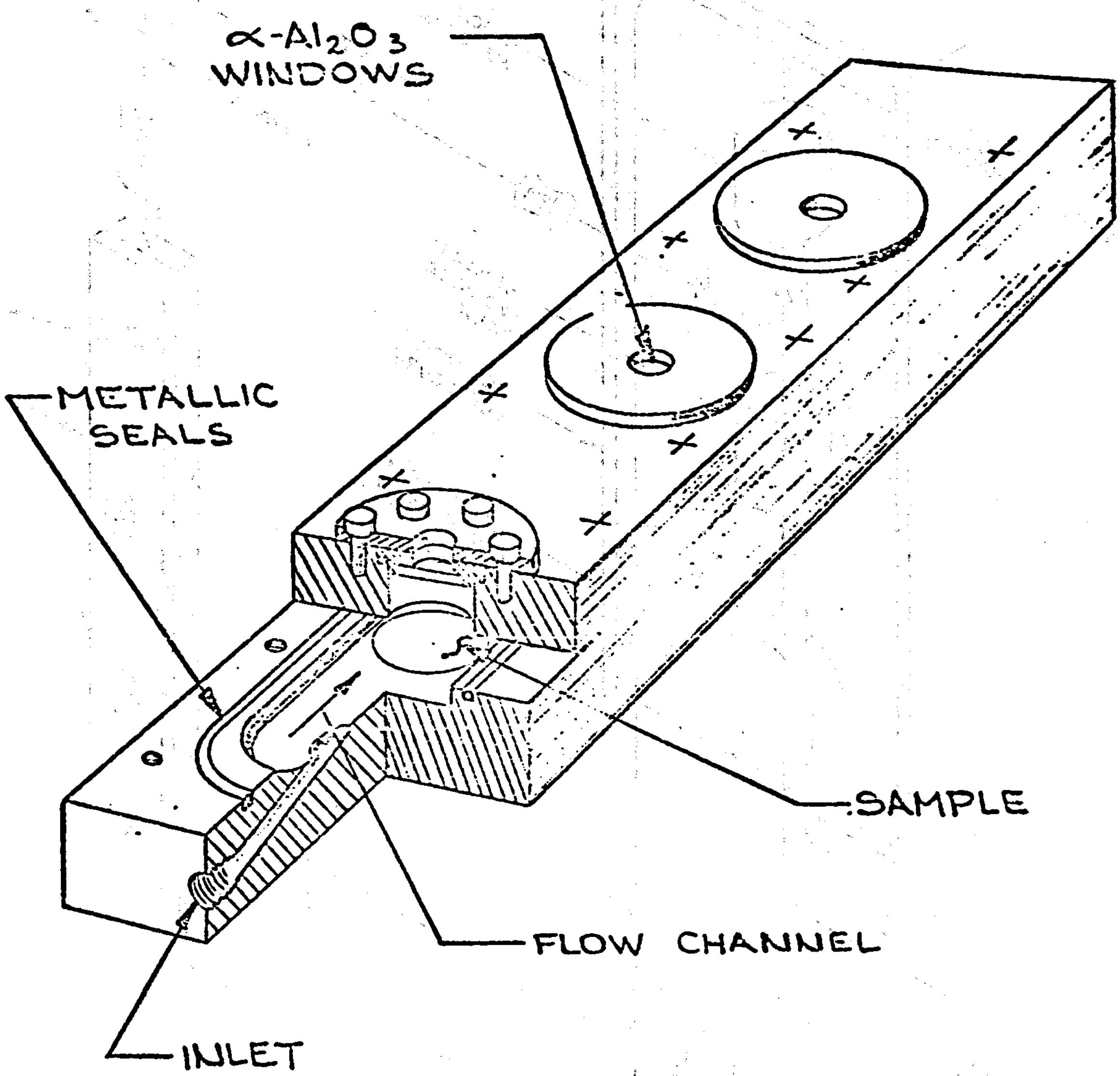
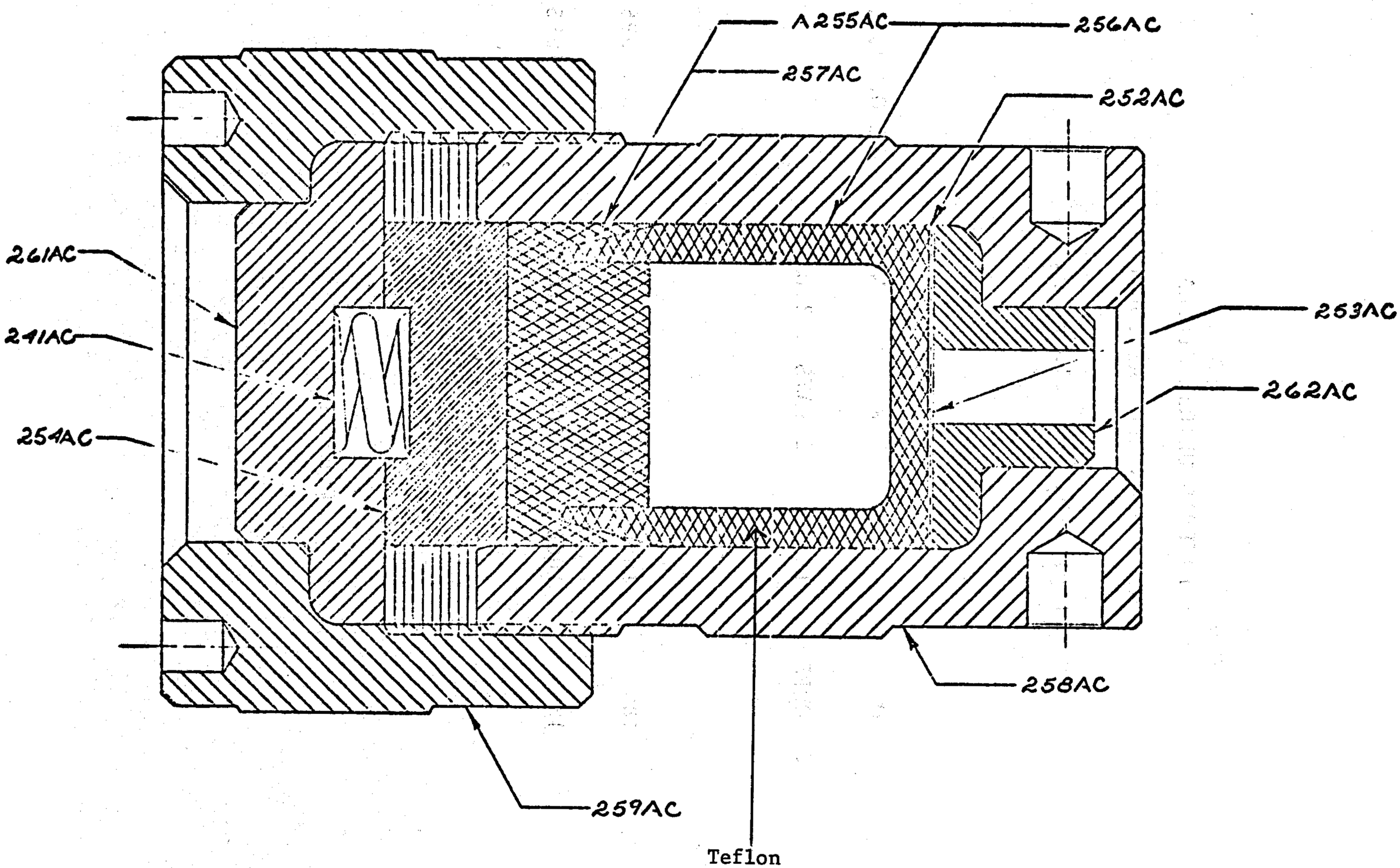



Figure 9. HEAT EXCHANGER ASSEMBLY




(Parr Instruments)

Figure 10. Steel bomb with Teflon liner.

BAKER'S ULTREX SILICA

IN TEFLON CUPS AT 200°C

.1 gm $SiO_2$ ~15 ml $H_2O$

| RUN NO. | O | P | R | N | AVE OF P,R, & N |
|---|---|---|---|---|---|
| TIME | 6 HOURS | 1 DAY | 2 DAYS | 2 DAYS | |
| ppm $SiO_2$ | | | | | |
| by $I/I_o$ | 486 | 1009 | 976 | 1000 | 995 |
| by AA | 480 | 1060 | 1005 | 1093 | 1053 |
| pH | 2.8 | 4.9 | 5.0 | 4.7 | |

Figure 11